ISBN: 978-3-95450-238-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2023-TUPDP077

TOWARDS THE ALBA II : THE COMPUTING DIVISION PRELIMINARY STUDY

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Abstract

The ALBA Synchrotron has started the work for upgrading the accelerator and beamlines towards a 4th generation source, the future ALBA II, in 2030. A complete redesign of the magnets lattice and an upgrade of the beamlines will be required. But in addition, the success of the ALBA II project will depend on multiple factors. First, after thirteen years in operation, all the subsystems of the current accelerator must be revised. To guarantee their lifetime until 2060, all the possible ageing and obsolescence factors must be considered. Besides, many technical enhancements have improved performance and reliability in recent years. Using the latest technologies will also avoid obsolescence in the medium term, both in the hardware and the software. Considering this, the project ALBA II Computing Preliminary Study (ALBA II CPS) was launched in mid-2021, identifying 11 work packages. In each one, a group of experts were selected to analyze the different challenges and needs in the computing and electronics fields for future accelerator design: from power supplies technologies, IOC architectures, or PLC-based automation systems to synchronization needs, controls software stack, IT Systems infrastructure or machine learning opportunities. Now, we have a clearer picture of what is required. Hence, we can build a realistic project plan to ensure the success of the ALBA II. It is time to get ALBA II off the ground.

THE ALBA II

The ALBA is a 3rd generation Synchrotron Light facility located in Spain. ALBA received its first users in 2012 and serves over 2,000 scientists annually. Currently, in 2023, ALBA has ten beamlines in operation, which will increase up to fourteen, one per year, when XAIRA, FAXTOR, MINERVA, and 3SBAR begin providing services to the scientific community (see Fig. 1).

In parallel, the facility is starting to leap from the 3rd to the 4th generation by upgrading the accelerator, the beamlines and building new instruments to complete the scientific portfolio [1], giving birth to the ALBA II.

Currently, most of the light sources are facing a complete overhaul of their sources, upgrading the magnet lattice to the Multi-Bend Achromat (MBA) already successfully used by SIRIUS, MAX IV and the ESRF. The upgrade brings an enormous increase in brilliance at the sample point (see Fig. 2).

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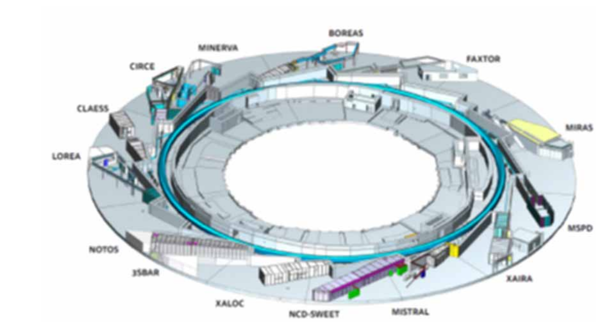

Figure 1: Current Layout of ALBA.

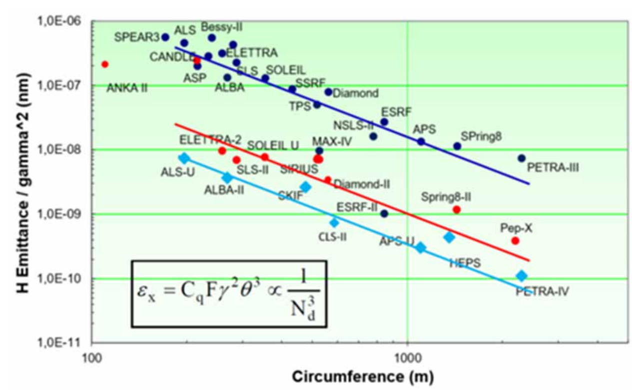

Figure 2: Landscape of current and future photon sources after MBA lattice upgrade [2].

Taking advantage of this increased photon beam quality also requires upgrades on the most critical parts of the beamlines. In addition, the increased luminosity allows for tackling sub-nanometer focusing beamlines. This latter case requires designing very long beamlines, with a length higher than 150m, which exceeds the boundaries of the building that houses the ALBA Synchrotron. Therefore, the endstation of these beamlines will require the construction of new technical buildings (see Fig. 3).

The Spanish and Catalonian governments have determined that the ALBA II project is a top science priority project for the country. The plots needed for placing the long beamlines have already been donated, and additional funding has been arrived for recruiting new staff for the studies of the new MBA lattice in the past two years. The next step, a multiannual funding agreement that will allow start executing the largest required investments, is expected for next year. The ALBA II project will completely upgrade the storage ring and maintain the linac and booster accelerators. In addition, the current operating beamlines will also

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be upgraded, and three new ones will be built, two of which will be long. A total portfolio of 17 beamlines is expected to be in operation by 2032 (see Fig. 4).

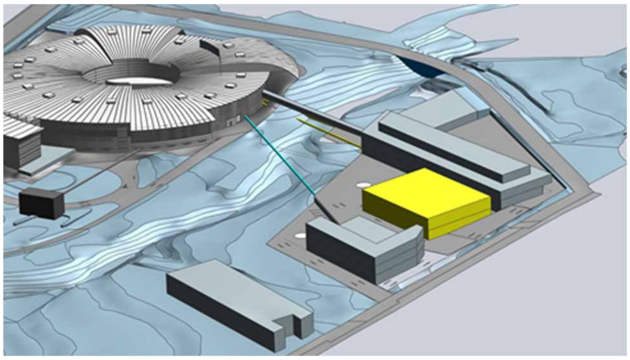

Figure 3: Sketch of the future long beamlines in the ALBA II.

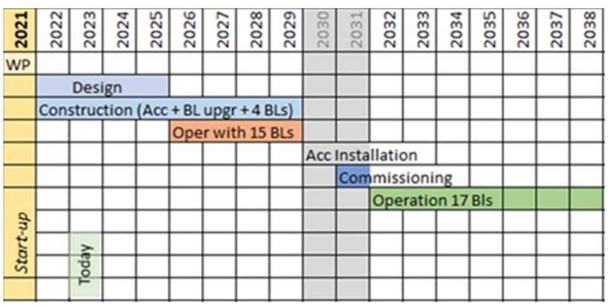

Figure 4: Schedule of the ALBA II project.

TURNING THE ENGINES ON IN THE COMPUTING DIVISION

Looking at the schedule, a complete overhaul of the ALBA synchrotron is ahead in the following years. The execution of a myriad of projects will be required. The necessity of designing the new magnet lattice or the tasks to construct the new beamlines is self-evident. However, the success of the ALBA II project will depend on many other factors. After twelve years of operation, it is necessary to revise all the subsystems of the accelerator that will be maintained. All possible ageing and obsolescence factors must be considered to guarantee their lifetime for the following decades. On the other hand, many technical enhancements have happened in the last years that improve the performance and reliability of different systems. In addition, using the latest technologies (both from the hardware and software perspective) will also avoid obsolescence in the medium term.

With these considerations, the project ALBA II Computing Preliminary Study (ALBA II CPS) started in mid-2021. First, 11 subsystems/fields were identified. In each one, a group of experts were selected to analyze the different challenges and needs for the future accelerator. The final objective was to build a strategic technical proposal for the future. After one year, the groups presented their first conclusions and, based on their outcomes, different follow-up actions started, some of which have extended up to 2023. All these activities must converge in March 2024, when a master project plan for ALBA II is required. The plan will comprise a resource-loaded schedule with budget implications, prioritizing the projects, fixing hard deadlines, and highlighting the critical paths.

This paper will present hereon the major conclusions reached by the different groups.

Power Supplies

The new lattices of 4th generation sources involve an increase in the required power converters. An initial estimate indicates that more than 1100 power supplies will be necessary for the ALBA II. On average, they will need less power to drive the magnets than the ALBA, but on the other side, the number of them that will be mission-critical will increase dramatically. That is, if there is a single failure in many of them, it will produce a beam loss. The accelerator's reliability can be severely affected by this increase. To mitigate this, it is important to consider architectural changes in the power converters in the future. On the other hand, the required power supplies are not expected to require increased stability, resolution, or repeatability compared to the current ALBA use.

An important aspect is the need to work closely with the accelerator's team responsible for designing the magnets to reduce the total number of different models. This reduction is crucial to use the resources in their design efficiently and reduce operational costs for spare parts to guarantee the accelerators' operation.

The ALBA II magnets' design is still in its early stages. Therefore, most of the efforts are currently invested in building a plan to guarantee the operation of the Booster Magnets power converters until 2060. In fact, some major replacements of custom power supplies have already started in 2023.

Motion Control

The IcePAP motor controller developed at the ESRF [3] has been the basis for the ALBA's standard motion control implementations. After many years of being part of the IcePAP collaboration, the results obtained from the performance and operational perspectives have been excellent. Consequently, there is no doubt in choosing to keep using the IcePAP in the future.

On the other hand, integrating new technologies such as piezoelectric motors will be required to achieve sub-nanometer resolutions. Mastering this technology will require a cross-disciplinary approach from mechanical, electronics, controls, and metrology engineering, which will be a major priority. To meet these requirements, a new nanomotion laboratory is currently being built to study new technologies and characterize the new instrumentation needed for the ALBA II.

Input/Output Controller Architecture

The CompactPCI standard, dated from 1995, is the basis for the ALBA accelerator Input/Output Controller (IOC) architecture. Generalized obsolescence problems will arise in the short term, so maintaining the same controller is discarded.

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From the hardware perspective, different options are considered as possible IOC controllers for the ALBA II: the cPCI Serial, the Micro TCA 4.0 or moving towards a model using open standards based on ARM processors with Linux embedded.

It's not a straightforward choice to make. The budgetary implications are considerable, but the repercussions in the Controls System Stack that must be built on top and the real-time processing requirements required in the different systems are even more critical. Postponing this evaluation to avoid over-dimensioning the architecture is a wise move at this stage until more mature specifications can be constructed.

Protection and Automation

In the ALBA, the PLC-based implementations of the Equipment Protection System (EPS) and the automation processes have been a success story. Based on the B&R manufacturer of PLCs, custom-designed software tools linked to the hardware configuration management system were built to ease the integration into the Control System. All the accelerator's and beamlines' EPS and automation processes use the same hardware and software stack, which is a major accomplishment. This has brought enormous operational benefits and reduced the workforce required to maintain and upgrade the different systems.

Once considering the ALBA II project, a major change is envisaged. In the ALBA design, there was no need to isolate the Booster and the Storage Ring systems; therefore, for example, the EPS vacuum system for the Booster and the Storage Ring are sharing resources. But now, in the ALBA II, the Booster will remain but the Storage Ring will be replaced entirely. Therefore, a first intervention to isolate both systems will be required. Afterwards, two projects must run in parallel: the first is the study of the new requirements for the EPS of the new Storage Ring system where, architecturally, the incorporation of the modern OPC Unified Architecture introduces clear benefits. The second is to ensure the operation of the automation systems for both the Booster and all the current beamlines. To prevent the coexistence of different systems, it's important to consider the option of renewing all the PLC-based systems' hardware. A rigorous resource analysis is necessary to assess the budget implications and, more importantly, the human resources required for it.

Another crucial component in the ALBA Synchrotron is the Personnel Safety System (PSS). The PSS system gives access to restricted areas to the accelerator and beamline hutches and checks radiation levels. Pilz's products are the current basis of the system, which has yielded good results. Despite that, some products are already obsolete and the system's inherent architecture makes it difficult to upgrade and maintain. Also, the logic definition must be overhauled to facilitate future upgrades. Finally, one lesson learned is that this system has minimal availability once in operation. Any modification or test in it requires the complete accelerator to stop. Due to this, building a Digital Twin on the system is considered mandatory to ease maintenance and upgrades.

Timing System

The ALBA Synchrotron timing system is built based on a bidirectional event system using Micro Research Finland hardware products [4]. The system's key parts are obsolete, so a complete replacement is necessary. There are two alternatives for the renewal: the first is replacing the hardware with compatible parts from the same manufacturer. And the second is to base the system on the White Rabbit protocol.

There is currently a running project funded by the EU Horizon 2020 program (LEAPS INNOV WP 5.3) studying the beamlines' synchronization needs and their integration with the accelerators' timing systems [5]. The outcome of this project will be analyzed carefully to find a more comprehensive approach to the facility's synchronization needs.

Configuration Management and Asset Management

ALBA has successfully used its own developed tool (CableDB) for hardware configuration management. After so many years, a careful analysis reached two main conclusions. The first is that the tool is ideally suited for reuse in the ALBA II accelerator. The second is that new developments are required to implement a comprehensive application management of assets. Specifically, stock management and life cycle tracking must be integrated across the entire organization. Consequently, the tool has undergone a significant upgrade [6].

Control System Software Stack

One of the most successful design choices in the ALBA has been using a common software stack for the control system in the accelerators and the beamlines. The decision has resulted in numerous benefits, including optimizing resources, flexibility in defining work teams, reusability of code, and facilitating support for the operation.

After evaluating the current software stack at the ALBA, it is clear that a complete redesign is required. The Control System Stack is a key component of the ALBA II; therefore, a detailed paper has been presented at this conference [7].

Scientific Data Management and IT Infrastructure

The scientific data management in the future accelerator is a relevant aspect to consider. Foreseeing the necessary IT infrastructures to store and process data will be crucial. In general, a more brilliant source produce increased data volumes. The sub-nanometer beamlines in particular are data-intensive producers. The ALBA II upgrade will boost the volumes of data generated in the ALBA, which is already experiencing a data deluge (see Fig. 5).

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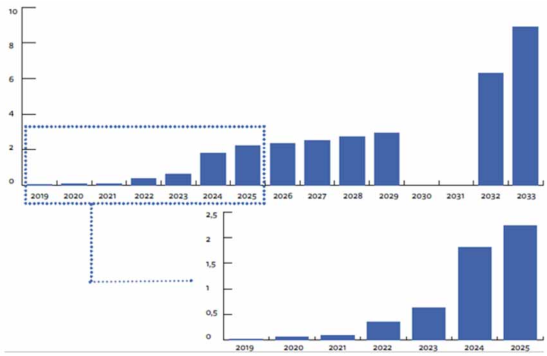

Figure 5: Estimation of Raw data generation.

Processing these volumes of data requires a specialized HPC IT Infrastructure. As a direct consequence, most ALBA II users will not have the required computing capabilities at their home institute to analyze the results of the experiments. Therefore, the ALBA II will require granting users access to the infrastructure and providing the tools for data analysis after the experiment.

Considering this scenario, an ambitious investment program for the IT infrastructure has been built as part of the ALBA II project (see Fig. 6).

	2023 – ALBA (current)	2029 - ALBA	2032 – ALBA II
Storage	4.7 PB	18 PB	34 PB
CPU Processing (nodes)	500	13.000	28.000
GPU Processing (CUDA cores)	12.500	190.000	400.000

Figure 6: IT infrastructure prospects at ALBA II.

In addition, a second data center will be necessary in the new technical buildings of the ALBA II to host these new infrastructures and archiving services. And during peak periods, Cloud Computing architectures will be required to complement the on-premise IT infrastructures.

Artificial Intelligence and Machine Learning

The growing use of machine learning and other AI algorithms is palpable in many domains. The number of applications is increasing, and benefits of the inertia in other areas. Currently, ALBA is not using these techniques to tackle any major projects. The slowness in adopting this emerging field comes from two major factors. The first is the lack of knowledge in this highly specialized domain. Secondly, the absence of an appropriate IT infrastructure to execute simple models makes it difficult to advance even when running simple simulations or training models. In such a scenario, various actions have started. The first is to increase the external training in such areas within the Division. The second is to execute a moderate investment in 2023 to acquire an infrastructure capable of computing such models. And the third one is to take profit of the commercial cloud to test different ML algorithms and choose the most appropriate GPU hardware solution for each scientific case.

CONCLUSION

The ALBA Synchrotron is already on its way towards the ALBA II. The additional plots required have been obtained, and the first two years of study for the updated magnet lattice have already given their first results. In parallel, the different groups at ALBA are putting in a lot of effort to build the ALBA II master project plan in March 2024. The grant of the increased multi-annual budget is expected for next year, which will enable the start of its execution. The plan will not be limited to the development needs for the new source. Still, it will include the required investments to guarantee operation for the following decades, the roadmap for the different technologies' adoption, and the strategic developments required to ensure the scientific success of the ALBA II. The conclusions that have already been made are summarized in this paper.

The road to reaching ALBA II is still lengthy. However, we have started at a brisk pace.

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